Studies of the Normal Basal Energy Requirement

BY

GRACE MacLEOD

DISSERTATION

Submitted in Partial Fulfillment of the Requirements
for the Degree of Doctor of Philosophy
in the Faculty of Pure Science,
Columbia University in the
City of New York.

NEW YORK CITY
1924

781
.72M
NCLASSED
ssertation

Studies of the Normal Basal Energy Requirement

BY

GRACE MacLEOD

DISSERTATION

Submitted in Partial Fulfillment of the Requirements
for the Degree of Doctor of Philosophy
in the Faculty of Pure Science,
Columbia University in the
City of New York.

NEW YORK CITY
1924

ACKNOWLEDGMENTS

This study was undertaken at the suggestion of Professor Mary S. Rose. The author wishes to express to Professor Rose her appreciation of the helpful advice and encouragement received throughout the course of the work.

The author wishes also to thank Professor Henry C. Sherman for his interest in the work and many helpful suggestions.

STUDIES OF THE NORMAL BASAL ENERGY REQUIREMENT

INTRODUCTORY

When protein, fat, or carbohydrate is oxidized in the body, oxygen is consumed, carbon dioxide is given off, and heat is produced. These processes are principally affected in a given individual by the two factors, ingestion of food and muscular activity. They are also influenced by the body temperature and that of the environment. These basic facts concerning energy metabolism were established by Lavoisier [1] who made the first quantitative measurements of the oxygen requirement of man. In 1789 he reported the results of experiments on his co-worker, Seguin, in which the consumption of oxygen per hour was determined with the subject (1) at rest, both with and without food, at ordinary room temperature, (2) at rest, without food, at lower temperatures, and (3) at work, both with and without food, at ordinary room temperature. When he determined the oxygen consumption of his subject at rest, without food, at room temperature, Lavoisier was actually obtaining a measure of what is today called basal metabolism and he clearly demonstrated that it is increased by exposure to cold, by the ingestion of food, and by work. By means of a method of gas analysis devised by Seguin the carbon dioxide excretion was also measured and the ratio of the volume of carbon dioxide excreted to the volume of oxygen consumed, known today as the respiratory quotient, determined. The results of these observations together with those of his work on animals caused Lavoisier to conclude that life processes are processes of oxidation resulting in the elimination of heat.

This work of Lavoisier's, as he himself recognized, clearly indicated the necessity of making determinations under as nearly like conditions as possible if results of measurements of oxygen consumption, or carbon dioxide excretion, or heat

production (energy metabolism) are to be comparable. The generally accepted conditions today are those of (1) complete muscular and mental repose, (2) the post-absorptive state, i. e., 12 to 18 hours after the last intake of food, (3) normal body temperature, and (4) ordinary room temperature. The heat production found under these standard conditions is called the "basal" or "standard" metabolism, the former term being the more commonly used. This component of the total energy requirement is sometimes spoken of as the overhead charge or the cost in Calories of running the machine when no external work is being done. It is the amount of energy required for sheer maintenance of the organism. Accurate knowledge of its magnitude is fundamental to estimates of food needs.

The present investigation was prompted by the fact that although basal metabolism determinations in fairly large numbers have been made on children from birth to 12 years of age and on men and women of from 18 years to old age, very little information exists as to the normal basal energy requirement between the ages of 12 and 18. While the age factor in basal metabolism is fairly small in adults, the Calories per 24 hours for the average adult decreasing 7.2 per year for men and 2.3 for women [2], in young children age exercises a very marked influence, the basal metabolism per unit of body weight rising to a maximum at about one year of age and from two years of age on decreasing gradually until it approaches the adult value. But attempts to plot curves showing the trend of basal metabolism throughout life reveal very few data for the age interval of 10 to 18 years, and the deficiency is greater for girls than for boys. Moreover, as reported by Benedict and Talbot [3] the break in the curve for girls and women is sharper than it is in that for boys and men. It was therefore considered important, if possible, to acquire data for the charting of this part of the curve for girls and with this object in view it was planned to make determinations on normal healthy girls from ten to eighteen years of age. Girls attending the Horace Mann School have served as subjects. Work was begun in January 1921. At the present time figures

for girls 11, 12, 13 and 14 years of age have been accumulated in sufficient numbers to justify definite conclusions.

PREVIOUS WORK

For half a century after the death of Lavoisier the study of energy metabolism was entirely neglected. About 1840 investigation in this field was again taken up and from that time to the present the work has continued, but it was not until 1899 that any reports on the basal metabolism of normal subjects appeared in the literature. Magnus-Levy and Falk [4] were the first investigators to plan and carry out a systematic investigation of the normal basal metabolism from childhood to old age. They used the Zuntz-Geppert open-circuit apparatus. They give results on seven girls of the ages considered in this study as follows:

Age, years	11	11	12	12	12	13	14
Cals. per 24 hrs.	1313	1459	962	938	1362	1217	1299

These results are the earliest which can be at all fairly compared with those of more modern work, but they were obtained under conditions less stringent than those imposed by present-day standards for basal energy determination.

Earlier reports than this, viz., those of Andral and Gavarret [5] in 1843, Scharling [6] in 1843, Speck [7] in 1892, and Sondén and Tigerstedt [8] in 1895, contain the results of determinations of the energy metabolism of a few girls of the ages studied here, but under conditions not basal. Speck, however, made the significant observation that although the 13- and 10-year-old girls whom he studied used less oxygen than a normal adult man in the same unit of time, when the results were calculated to the oxygen consumed per kilogram of body weight, the metabolism of the girls was found to be higher than that of the man. He concluded that a small body absorbs relatively more oxygen than a larger one and that in the growing organism the consumption of oxygen is greater than in the adult. Although Speck's results cannot be compared with those of the modern work on basal metabolism, this general conclusion of his is of interest in the light of the facts as known today.

The work of Sondén and Tigerstedt also should be noted. In 1895 they published the description of a large respiration chamber built by them in Stockholm and at the same time reported the results of experiments carried out in it for the purpose of determining the carbon dioxide output of groups of subjects, the results of which were to be used in planning the ventilation of schoolrooms, public buildings, etc. With this object in view they made their observations under conditions as much as possible like those which would prevail in such rooms. For information concerning schoolrooms their usual procedure was to make observations on groups of six subjects at a time, the children sitting quietly in chairs, reading, and often being allowed to eat apples or candy. Hence, the results cannot be compared with those of experiments carried out under conditions agreed upon by common consent as suitable for basal determinations, but Benedict and Talbot [3] assuming a respiratory quotient of 0.90 and using their minimum amounts of carbon dioxide excreted per six individuals per half hour, have calculated the Calories per kilogram per 24 hours. The results obtained on girls of 11 to 14 years, calculated to the basis of Calories per 24 hours (using the average body weight of the group) are:

Age, years	11	12	13	14
Cals. per 24 hrs.	1603	1720	1671	1803

After the work of Magnus-Levy and Falk in 1899, the literature contains no further observations on the basal metabolism of girls until 1914 when Benedict, Emmes, Roth, and Smith [9] in a report on the basal metabolism of normal men and women included among their figures results obtained on 7 girls of ages 15 to 18. The apparatus used was the Benedict Universal Respiration Apparatus. Modern standard conditions for basal metabolism determinations were observed in making all these observations. The results obtained were:

Age, years	15⅓	15½	15⅔	16$^{5}/_{12}$	18	18	18
Cals. per 24 hrs.	1630	1353	1541	1273	1235	1262	1475

In 1921 Benedict and Talbot [3] reported 10 observations on girls of the age-range considered here. In this work respira-

tion chamber apparatus was used and modern standard conditions for determination of basal metabolism were observed throughout. The figures obtained were:

Age, years	Cals. per 24 hours	Age, years	Cals. per 24 hours
9¾	919	11	984
10¼	999	11 11/12	1062
10½	896	12 1/12	1500
10½	923	12⅙	1012
10⅚	944	13⅓	1318

The next observations on girls are those of Benedict and Hendry [10] in 1921 and of Benedict [11] in 1923 on groups of Girl Scouts. Twelve girls of the same age slept in a respiration chamber throughout the night and their carbon dioxide production was measured for every half-hour or hour period during the night. In these experiments oxygen consumption was also determined for a certain period by stopping ventilation after the minimum carbon dioxide production had been reached, letting the carbon dioxide accumulate to from 1.6 to 1.8 times the normal figure and then with the Sondén apparatus making a determination of the percentage of the carbon dioxide and oxygen in the air. In this way the respiratory quotient could be determined so that results were not obtained from carbon dioxide figures alone. The results were:

Age, years	Cals. per 24 hours	Age, years	Cals. per 24 hours
12⅙	1180	14	1331
12⅚	1226	14 1/12	1266
13⅓	1188	14⅚	1254
13⅔	1382	15⅚	1170
14	1314	17	1258
		17 11/12	1253

In 1923, reporting upon the energy expenditure and food requirements of children at school, Bedale [12] gives basal metabolism figures for girls from 7 to 17 years of age. Although her observations were made on individual children she averaged the results for all the children of the same age and reports these means as the average basal metabolism for that age.

Her groups varied in size from 2 to 10 in number. Her average figures for the age groups considered here are:

Age, years	10	11	12	13	15	16	17
Cals. per 24 hrs.	988	1498	1402	1478	1456	1363	1349

The figure for 14 years is omitted because it was obtained on only one girl who is reported by Miss Bedale as not being up to standard in physique and vitality.

In this work of Bedale the Douglas bag with face mask was used and the observations were made upon the subjects in bed before they arose in the morning. The gas analyses were made with the Haldane apparatus.

APPARATUS

The apparatus used in the work reported here was the Sanborn Benedict Portable Respiration Apparatus [13]. The method is that of indirect calorimetry and the apparatus is of the closed circuit type in which the respiratory tract is connected with an enclosed circulating stream of oxygen-enriched air by means of a mouth piece and nose clip, the exhaled carbon dioxide being removed from the air by soda-lime placed in the closed system for this purpose. By means of a blower in the system the air is circulated at a rate of 26 to 30 liters per minute in the direction indicated by the arrows in the diagram. The water-sealed spirometer is counterpoised over a pulley by a weight to which is attached a pointer which moves over a graduated scale as the bell rises and falls with the expirations and inspiration of the subject. The spirometer therefore serves as an adjusting device or expansion chamber in the system to accommodate the changes in pressure due to respiration. By means of the graduated scale the change in level of the bell as oxygen is absorbed from the air is measured, giving the volume in cubic centimeters of oxygen consumed. A thermometer is mounted in the top of the spirometer bell to indicate changes in temperature in the enclosed air.

In this type of apparatus oxygen consumption only is measured, no attempt being made to determine the carbon dioxide

because of the known capacity of the body to store carbon dioxide and the effect this would have on determinations made over a short period of time. But it is to be noted, aside from the question of this error, that of the two determinations that of

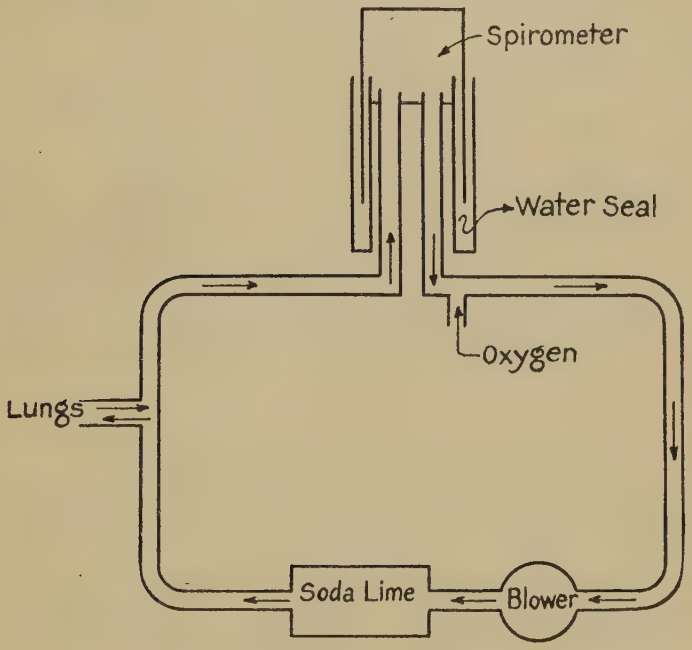

Diagram of Apparatus

the oxygen alone is more valuable than that of the carbon dioxide alone since the calorific value of a liter of oxygen varies much less with the character of the material oxidized than does that of carbon dioxide. At a respiratory quotient of 1.00 (carbohydrate being burned) the calorific value of a liter of carbon dioxide is 5.047 Calories and at that of 0.70 (fat being burned) it is 6.694, a difference of 1.647 Calories per liter, or of 32.6 per cent. In contrast with this the corresponding values for oxygen are 5.047 and 4.686 respectively, a difference

of 0.361 Calories, or of 7.7 per cent., less than one-fourth the variation for carbon dioxide. It is evident, therefore, that if only one of the two is to be determined in any method of indirect calorimetery, the figures for oxygen consumption may be expected to give more reliable results than those for carbon dioxide excretion. Benedict, Emmes, Roth and Smith [9] have shown that the average respiratory quotient of the human subject in the post-absorptive condition, in a state of muscular and mental repose, and with the body temperature normal is 0.82. At this respiratory quotient the energy value of oxygen is 4.825 Calories per liter and this is the equivalent used in calculating the heat production from the oxygen consumption measured by this apparatus. Using this equivalent when the actual respiratory quotient is as low as 0.77 or as high as 0.87, instead of being 0.82 as assumed, introduces an error of only 1.3 per cent.

EXPERIMENTAL PROCEDURE

The standard conditions for determination of basal metabolism have been observed in this work, namely:

1. **Complete muscular and mental repose**—To secure muscular repose the subject is required to rest quietly, lying down, for 25 to 35 minutes before observations are begun. Boothby and Sandiford [14] have shown that 20 to 40 minutes of rest suffice to obtain the degree of muscular relaxation desired for the basal metabolism determination. Little difficulty has been encountered in this study in securing the co-operation of the subjects in preserving muscular repose during the tests. Whether or not mental repose is secured is not so easily determined, but in the normal healthy child it is seldom a difficult factor except perhaps the first time she serves as subject when there may be a feeling of apprehension or excitement. To determine how great a factor the novelty of the experience may be, the results of the first tests on all subjects have been averaged separately from those of all later tests as shown in Table I.

TABLE I

AVERAGES OF FIRST TESTS COMPARED WITH THOSE OF LATER TESTS

Age Years	Cals. per sq. m. per hr. First Test	Later Tests
11	37.4	37.7
12	43.5	38.7
13	41.7	40.7
14	35.5	37.5
Average	39.5	38.7

It will be seen that the influence of the novelty of the experience is not uniform and does not greatly affect the average result. In plotting the results, however, first and later tests have been distinguished by using a cross for the results of first and a circle for those of later observations.

2. **The post-absorptive state**—By the post-absorptive condition is meant the state of the body when it is doing none of the work which results from the ingestion of food. To meet this requirement for the test, subjects are asked to come to the laboratory at 8 A. M. without having eaten any food since dinner the night before. As dinner in the majority of cases is eaten at 6:30 P. M., subjects have usually been fasting about 14 hours when observations are begun at or near 8:30 A. M. Twelve to eighteen hours after the last intake of food is the commonly accepted standard time.

3. **Normal body temperature**—Du Bois [15] has shown that each centigrade degree increase in body temperature above the normal increases the basal metabolic rate about 13 per cent., a result indicating that the reactions in fever respond to a rise in temperature according to van't Hoff's law, the temperature coefficient in practically all his fever experiments being within the limits 2 to 3 and averaging 2.3. It is essential, therefore, that body temperature be normal at the time of a basal metabolism determination. Temperature on these subjects is not always recorded as their normality has been assured by reports from the school physician's office, these children being

at all times under careful medical supervision. Recently, however, it has been made a matter of routine to take the body temperature sub-lingually before beginning observations.

While the subject is resting 25 to 35 minutes to recover from the muscular activity incident to rising, dressing and coming to the laboratory, motor and blower are oiled and the apparatus tested for tightness. With the spirometer bell elevated somewhat above its lowest position, a weight of 150 grams is placed on it and with the blower running, a scale reading is taken and the time and the temperature noted simultaneously. If in 15 minutes there has been no change in the scale reading, or only such as can be accounted for by change in temperature, the apparatus is considered tight. Then the valve at the mouth piece is opened and the apparatus swept out by pushing the spirometer bell down to its lowest position. After closing the mouth piece valve again, oxygen is introduced in quantity somewhat more than sufficient for a 10 to 12 minute test. This amount can be calculated roughly on the basis of oxygen consumption averaging approximately 250 cc. per minute. Benedict and Higgins [16] have shown that the gaseous metabolism of the human subject is not affected by the breathing of oxygen-rich air.

The subject is then fitted with the nose clip and the mouth piece adjusted. A 3-way valve at the mouth piece enables one to supply the subject with air either from that of the room or from that enclosed in the apparatus. When the valve has been turned, making the respiratory tract a part of the closed circuit, the excursions of the bell are watched until normal and regular respiration is established. The scale reading at the end of an expiration is then noted and at the same instant the stop watch started and the temperature at the top of the bell taken. Duplicate observations are made by using a second stop watch or by having a second observer take independent readings. After 10 to 12 minutes the scale reading is again taken at the end of a normal expiration, the watch stopped simultaneously, and the temperature again noted. Mouth piece and nose clip are removed and while the stop watches are read and a fresh supply of oxygen introduced into the appar-

atus, the subject lies still in readiness for a second period which is begun as promptly as possible. At least two periods are carried through on every subject and two independent sets of readings made in each period.

In order to know whether any leaking occurs during the test period, the scale is read every minute, taking the reading each time at the end of the expiration which coincides most nearly with the end of the minute. Between the third and fourth or the fourth and fifth minutes a weight of about 30 grams is placed on top of the bell. If these minute readings, when plotted, make a straight line, there has been no leak during the period. If a leak has occurred, it will have been increased by putting the weight on the bell and the plotted line will show a change in direction at the point at which the weight was put upon the bell.

The average of the spirometer temperatures at the beginning and end of a period is used as the temperature at which the oxygen was supplied to the subject. The difference between the scale readings gives the volume of oxygen consumed.

The barometer is read at the beginning, during, and at the end of the periods of observation and the average reading used in the computations.

Pulse and respiration rates are determined frequently throughout the observations, the pulse rate by counting at the wrist, the respiration rate by counting complete excursions of the bell.

Body weight without shoes but in indoor clothing is determined to the nearest tenth of a kilogram. Nude weight is calculated from this weight by applying the corrections used by Baldwin and Wood [17], the results having been found to be in very close agreement with those obtained by subtracting the average weight of clothing as determined by actually weighing the clothes worn by a number of the girls of each age group.

Both standing and sitting height are determined on a stadiometer the scale of which is graduated to tenths of a centimeter.

Vital capacity is determined by the use of a vital capacity spirometer, the scale reading to tenths of a liter, the procedure observed being that of Dreyer [18].

Body surface area is estimated from the Du Bois height-weight surface area chart [19].

Age is recorded as that at the nearest birthday, for example, a child who is 11 years 6 months old or over but not as much as 12 years 6 months is classified as a 12-year-old.

Tests are made at frequent intervals of the ventilation rate in the system and of the efficiency of the soda lime. It has been found that one jar of soda lime will remove the carbon dioxide of over 300 minutes' actual running time with a subject on the system. As a routine matter 300 minutes is made the maximum time for using one jar of the absorbent.

COMPUTATION OF THE RESULTS

The true decrease in the volume of air in the system should be obtained by reducing the total volume in the apparatus at the beginning and at the end of a period to 0° C. and 760 mm. and then subtracting. When results obtained in this way [13, 20] are compared with those obtained by correcting to 0° C. and 760 mm. the difference between spirometer readings at the beginning and end, the discrepancy averages 37.4 cc. per degree centigrade rise in temperature during the period. For the sake of simplifying calculations and because the error introduced will be well within the limits of error of the method as a whole, it is considered justifiable to add to the volume of oxygen, as given by the fall of the spirometer, before making any other corrections, 37.4 cc. for each centigrade degree rise in temperature during the test. The resulting volume is then reduced to 0° C. and 760 mm., the average barometer reading being corrected for brass scale reading and the tension of aqueous vapor. The air in the apparatus is saturated with water vapor from the water seal and the moisture exhaled by the subject. The corrected volume divided by the length of the period in minutes, as read to tenths of a second from the stop watch, gives the oxygen consumption per minute and from this, assuming a respiratory quotient of 0.82, the heat production in Calories

can be computed. In the table of results the heat production is given in the four different ways in which it is customary to state it,—Calories per 24 hours., Calories per sq. m. per hr., Calories per sq. m. per 24 hrs., and Calories per kg. per 24 hrs.

The work of computation is much simplified by the use of the tables compiled for this purpose by Carpenter [21] from such sources as the Smithsonian, Landolt-Börnstein and other tables. Four-place logarithm tables are used throughout.

DISCUSSION OF RESULTS

The individual results have been assembled in Table II. The average figures for each age group are brought together in Table III.

TABLE III

AVERAGE RESULTS FOR EACH AGE GROUP

Age Yrs.	Av. Cals. per 24 hrs.	Av. Cals. per sq. m. per hr.	Av. Cals. per sq. m. 24 hrs.	Av. Cals. per kg. per 24 hrs.	Av. cc. oxygen per min.	Av. pulse rate	Av. respiration rate	Av. vital capacity Liters
11	1191	37.5	900	29.2	171	77	16.6	....
12	1295	41.3	990	32.3	185	77	17.6	2.27
13	1365	41.0	985	31.1	196	76	15.6	2.75
14	1308	36.6	880	26.7	188	73	16.0	2.84

In Table IV are presented the results of a statistical treatment of the basal metabolism results, expressed in Calories per square meter of body surface per hour, for each of the four age groups studied.

TABLE IV

RESULTS IN CALORIES PER SQUARE METER PER HOUR TREATED STATISTICALLY

Age Yrs.	Mean	Standard Deviation	Coeff. of Var. Per cent.	Probable Error of Mean
11	37.5	± 1.50	4.0	± 0.36
12	41.3	± 4.65	11.3	± 0.57
13	41.0	± 4.30	10.5	± 0.47
14	36.6	± 2.94	8.0	± 0.48

TABLE II—RESULTS OF INDIVIDUAL DETERMINATIONS

Subject No.	Date	Age Yrs.–Mos.	Wt. clothed but without shoes Kgs.	Calc'd Nude Wt. Kgs.	Height Standing Cms.	Height Sitting Cms.	Body Surface Area Sq. m.	Average Pulse Rate	Average Respiration Rate	Vital Capacity Liters	Oxygen Consumption cc./min.	Cals. per 24 hrs.	Basal Metabolism Cals. per kg. per 24 hrs.	Basal Metabolism Cals. per sq.m. per hr.	Basal Metabolism Cals. per sq.m. per 24 hrs.
		11 yrs.													
22	May 10, '21	11-1	46.6	45.7	155.7	....	1.43	82	11.5	....	185	1286	27.6	37.5	900
15	Mar. 12, '21	10-10	44.1	43.2	149.7	....	1.36	84	....	....	177	1229	27.9	37.7	905
15	Apr. 16, '21	10-11	44.3	43.4	150.3	....	1.37	76	15	....	175	1217	27.5	37.0	888
15	Apr. 27, '21	11-0	43.9	43.0	149.7	....	1.36	90	18	....	166	1153	26.3	35.3	847
16	Mar. 12, '21	10-10	35.4	34.5	147.3	....	1.22	70	....	....	152	1057	29.9	36.1	866
16	Apr. 27, '21	10-11	37.2	36.3	146.6	....	1.25	68	20.5	....	175	1217	32.7	40.6	974
8	Feb. 23, '21	10-11	38.2	37.3	153.0	....	1.29	75	....	....	169	1178	30.8	38.1	914
8	Apr. 20, '21	11-1	39.1	38.2	154.0	....	1.32	73	18	....	171	1192	30.5	37.7	905
		12 yrs.													
13	Mar. 5, '21	11-9	43.8	42.9	149.0	....	1.36	98	....	....	196	1361	31.1	41.8	1003
13	Apr. 23, '21	11-10	44.0	43.1	151.1	....	1.37	83	16	....	200	1392	31.6	42.3	1015
22	Mar. 22, '22	11-11	50.7	49.8	161.6	84.7	1.52	70	12.5	2.66	200	1394	27.5	38.2	917
11	Feb. 26, '21	11-7	34.1	33.2	141.5	....	1.17	77	....	....	165	1145	33.6	40.8	979
11	Apr. 5, '21	11-8	33.8	32.9	142.2	....	1.17	78	18	....	128	893	26.4	31.8	763
35	Apr. 28, '23	12-4	45.8	44.9	155.9	80.0	1.42	80	16.5	2.24	186	1293	28.2	38.0	912
35	May 12, '23	12-4	45.0	44.1	155.8	79.7	1.41	79	18.5	2.24	199	1387	30.8	41.0	984
29	Apr. 26, '22	11-9	40.4	39.5	148.5	75.7	1.29	95	17.5	2.20	199	1386	34.3	44.8	1075
29	June 5, '22	11-10	41.3	40.4	150.4	77.4	1.32	81	14	2.42	189	1316	31.9	41.5	996
12	Mar. 2, '21	11-9	44.4	43.5	152.2	....	1.37	68	....	....	181	1261	28.4	38.4	922
12	Apr. 19, '21	11-11	44.6	43.7	153.4	....	1.38	59	....	....	167	1164	26.1	35.2	845
5	Feb. 5, '21	12-5	40.5	39.6	154.8	....	1.34	77	....	....	200	1391	34.3	43.3	1039
33	Dec. 9, '22	12-3	45.0	44.1	151.8	80.3	1.38	77	14.5	2.59	222	1545	34.3	46.7	1121
33	Dec. 16, '22	12-4	45.0	44.1	151.8	80.5	1.38	66	15	2.58	205	1428	31.7	43.1	1034
19	Apr. 2, '21	11-8	27.0	26.1	135.3	....	1.02	67	12	....	159	1108	41.0	45.3	1087
19	May 3, '21	11-9	26.9	26.0	134.0	....	1.02	63	12	....	157	1089	40.5	44.5	1068
1	Jan. 22, '21	12-5	48.2	47.3	166.5	....	1.53	87	....	....	203	1412	29.3	38.5	924
25	Apr. 12, '22	11-8	42.4	41.5	155.8	81.4	1.37	69	19.5	2.42	208	1446	34.1	44.0	1056
24	Apr. 7, '22	11-11	34.5	33.6	148.8	78.9	1.22	91	16	2.30	194	1351	39.2	46.2	1109
36	Apr. 28, '23	12-4	40.6	39.7	154.0	77.5	1.34	74	18	2.15	216	1501	37.0	46.7	1121
36	May 19, '23	12-4	40.5	39.6	154.0	77.6	1.34	74	14.5	2.13	195	1355	33.5	42.2	1013
8	Apr. 1, '22	12-0	43.0	42.1	160.6	82.3	1.42	73	22	2.22	197	1372	31.9	40.3	967
26	Apr. 12, '22	11-7	39.5	38.4	151.3	81.0	1.30	98	25	2.28	214	1490	37.7	47.8	1147
26	June 7, '22	11-9	40.4	39.5	152.5	83.0	1.32	86	20.5	2.37	137	956	23.7	30.2	725
9	Feb. 23, '21	11-7	38.0	37.1	151.7	....	1.28	84	....	....	194	1348	35.5	43.9	1054
9	Apr. 13, '21	11-9	38.9	38.0	153.0	....	1.31	76	18.5	....	142	987	25.4	31.4	754
30	Apr. 26, '22	12-3	32.8	31.9	135.8	72.3	1.12	79	19.5	1.68	178	1237	37.7	46.0	1104
30	June 5, '22	12-4	34.0	33.1	137.8	73.0	1.14	79	23.5	1.77	132	1222	35.9	44.7	1073
7	Feb. 19, '21	11-7	45.9	45.0	147.8	....	1.37	65	....	....	207	1442	31.4	43.9	1054
7	Apr. 9, '21	11-9	46.4	45.5	149.0	....	1.38	60	24	....	169	1177	25.4	35.5	852
		13 yrs.													
37	May 5, '23	12-8	34.6	33.7	147.5	77.1	1.21	70	7.5	2.49	174	1209	34.9	41.7	1001
22	Dec. 15, '22	12-8	53.5	52.4	164.6	86.7	1.58	73	14	2.98	219	1523	28.5	40.2	965
22	May 4, '23	13-1	55.3	54.4	165.6	86.9	1.61	71	13	3.07	207	1443	26.1	37.4	898

23	Apr. 7, '22	13-2	48.9	48.0	164.7	85.3	1.52	89	16.5	2.91	235	1635	33.4	44.9	1078
23	June 7, '22	13-4	48.8	47.9	166.0	85.5	1.53	79	18	3.06	188	1311	26.9	35.7	857
11	Mar. 25, '22	12-8	42.0	41.1	150.4	78.4	1.32	80	14	2.34	193	1346	32.1	42.5	1020
11	June 6, '22	12-11	41.2	40.3	150.8	78.4	1.32	75	18.5	2.19	163	1133	27.5	35.8	859
17	Mar. 16, '21	12-10	37.3	36.4	140.6	....	1.21	98	....	....	181	1262	33.8	43.5	1044
17	Apr. 21, '21	12-11	37.2	36.3	145.2	....	1.23	90	22	....	195	1357	36.5	46.0	1104
29	Apr. 26, '23	12-9	48.1	47.2	157.3	82.3	1.46	79	15.5	2.62	198	1375	28.6	39.2	941
33	Apr. 14, '23	12-8	45.2	44.3	154.7	81.3	1.41	72	14	2.84	208	1445	32.0	42.7	1025
33	May 26, '23	12-9	45.8	44.9	155.6	82.0	1.42	72	13.5	2.98	199	1388	30.3	40.7	977
14	Mar. 5, '21	12-11	39.3	38.4	155.5	....	1.33	76	....	....	195	1355	34.5	42.5	1020
14	Apr. 23, '21	13-0	39.2	38.3	157.0	....	1.34	81	12	....	239	1662	42.4	51.7	1241
6	Feb. 5, '21	13-0	48.0	47.1	169.6	....	1.54	88	....	....	188	1310	27.3	35.5	852
3	Jan. 29, '21	12-10	31.8	30.9	140.7	....	1.17	68	....	....	171	1191	37.5	42.4	1018
3	Apr. 30, '21	13-1	32.8	31.9	140.8	....	1.14	61	21	....	141	981	29.9	35.9	862
15	May 16, '23	13-1	57.8	56.9	161.6	85.8	1.62	78	14	3.01	208	1451	25.1	37.3	895
19	Mar. 25, '22	12-8	30.1	29.2	138.0	72.9	1.09	67	10	2.30	164	1143	38.0	43.7	1049
19	June 6, '22	12-10	30.3	29.4	139.2	73.2	1.09	65	11.5	2.36	150	1046	34.5	40.0	960
38	May 7, '23	13-1	55.8	54.9	155.4	82.0	1.54	79	12.5	2.84	194	1350	24.2	36.5	876
2	Jan. 22, '21	12-11	56.5	55.6	159.5	....	1.57	82	....	....	216	1503	26.6	39.9	958
32	Nov. 25, '22	12-10	51.4	50.5	153.5	82.5	1.48	71	15.5	2.51	245	1703	33.1	48.0	1152
32	Dec. 9, '22	12-11	52.7	51.8	153.7	81.8	1.49	68	16.5	2.51	241	1674	31.8	46.9	1126
32	Apr. 21, '23	13-5	54.7	53.8	156.2	83.7	1.53	64	19	2.91	218	1517	27.7	41.3	991
16	May 9, '23	12-11	49.0	48.1	155.5	82.3	1.47	58	15	3.09	180	1254	25.6	35.6	854
8	May 7, '23	13-1	44.4	43.5	165.9	85.4	1.47	67	14	2.78	186	1296	29.2	36.7	881
34	Dec. 16, '22	12-7	46.5	45.6	155.6	84.5	1.44	81	15	2.94	224	1558	33.5	45.1	1082
34	May 12, '23	13-0	48.7	47.8	157.3	85.6	1.47	82	16.5	3.18	231	1609	33.0	45.6	1094
34	May 26, '23	13.0	48.7	47.8	156.9	85.0	1.46	76	15.5	3.17	199	1383	28.4	39.5	948
4	Jan. 29, '21	13.2	44.4	43.5	146.7	....	1.34	75	....	....	182	1269	28.6	39.5	948
4	Apr. 30, '21	13-5	48.0	47.1	148.7	....	1.42	69	24	....	176	1223	25.5	35.9	862
31	Nov. 18, '22	12-11	40.0	39.1	150.0	79.8	1.30	86	17	2.59	185	1289	32.2	41.4	994
31	Nov. 25, '22	12-11	40.3	39.4	151.0	79.7	1.31	86	17	2.69	179	1242	30.8	39.5	948
31	Apr. 14, '23	13-4	43.4	42.5	153.7	81.9	1.40	77	17	2.95	182	1267	29.2	37.7	905
31	Apr. 21, '23	13-4	44.0	43.1	153.2	81.9	1.38	83	17.5	2.96	184	1280	29.1	38.7	929
9	Apr. 1, '22	12-8	40.5	39.6	157.2	80.6	1.36	76	13	2.20	208	1448	35.8	44.3	1063
30	Apr. 26, '23	13-3	47.7	36.8	145.7	77.0	1.24	73	19.5	2.44	207	1440	38.2	48.4	1162
		14 yrs.													
39	May 11, '23	13-7	44.6	43.6	157.5	81.1	1.40	70	16	2.61	176	1221	27.4	36.4	874
23	May 5, '23	14-3	54.7	53.7	168.2	87.4	1.64	86	14	3.20	240	1670	30.5	42.4	1018
20	Apr. 16, '21	14-2	63.2	62.2	169.2	....	1.73	78	15.5	....	211	1468	23.2	35.4	854
20	May 14, '21	14-3	63.4	62.4	169.5	....	1.74	88	14.5	....	230	1601	25.3	38.4	922
18	Mar. 16, '21	14-3	32.2	31.2	139.8	....	1.13	98	....	....	131	911	28.3	33.6	806
12	Dec. 15, '22	13-7	59.5	58.5	159.7	85.9	1.62	75	19.5	3.03	213	1484	24.9	38.2	917
12	May 4, '23	13-11	56.5	55.5	160.8	86.3	1.59	63	16.5	3.48	198	1380	24.4	36.2	869
43	May 19, '23	13-7	48.1	47.1	157.5	80.0	1.47	78	13	3.19	165	1149	23.9	32.6	782
27	Apr. 15, '22	14-3	50.8	49.8	161.0	82.0	1.53	57	13.5	3.03	184	1279	25.2	34.9	838
3	Mar. 20, '22	13-11	36.0	35.0	145.4	76.8	1.23	61	17	....	165	1150	31.9	38.9	934
3	June 8, '22	14-2	39.1	38.1	146.5	77.2	1.26	69	21	2.39	140	974	24.9	32.3	775
4	Mar. 20, '22	14-3	52.0	51.0	155.2	79.6	1.49	69	19.5	2.59	185	1285	24.7	35.9	862
4	June 8, '22	14-5	51.0	50.0	157.0	80.0	1.49	65	18	2.89	165	1145	22.5	32.0	768
41	May 18, '23	13-7	41.4	40.4	161.0	82.4	1.39	68	15.5	2.65	174	1211	29.3	36.3	871
9	May 9, '23	13-10	45.1	44.1	165.0	83.6	1.48	76	11	2.35	202	1402	31.1	39.5	948
7	May 14, '23	13-10	56.4	55.4	157.8	85.2	1.57	56	14	2.86	220	1533	27.2	40.7	977
42	May 18, '23	13-11	47.6	46.6	158.5	86.0	1.45	77	18	2.60	196	1365	28.7	39.2	941

It should be emphasized that the only results in the literature with which these results are strictly comparable are those of Benedict and Talbot [3] since these are the only investigators giving figures obtained on normal individual subjects at the ages of the subjects reported on here. Bedale [12], although working with individuals, does not, unfortunately, give the individual results.

Benedict and Talbot [3] plotted the results of their work on children and drew what they considered to be representative average curves to show the trend of the normal basal metabolism from birth to puberty. Beyond eleven years the curves were projected with very few cases to support them. It was thought that perhaps the most graphic way to present the results of this study would be to plot them on these Benedict and Talbot curves to see what effect, if any, they would have upon the trend of the line as drawn by these investigators. Also, in order to bring together all the available basal metabolism figures for normal girls up to seventeen or eighteen years of age, whether group or individual results, and thus obtain as true a representation as possible at the present time of the trend of the basal energy requirements for this period for girls, there have been charted on these curves, along with the results of this study, the Benedict and Emmes, Girl Scout, and Bedale values. Examination of Figures 1 to 7 inclusive will show the effect which these results have upon the trend of the lines drawn by Benedict and Talbot. It should be kept in mind in examining these curves that the Girl Scout values are from observations made while the subjects were asleep and the Benedict and Talbot figures were obtained on children who were sometimes awake and sometimes asleep. This may account for some of the discrepancy between them and the results obtained in this study of girls of the same age range, since it is well known that sleep has a depressing effect upon the metabolism. Of the seven Benedict and Talbot curves on which the later data have been charted those in which the trend of the proposed line is the least affected are those in which the basal metabolism per square meter of body surface is referred to age and to weight and the Calories per 24 hours

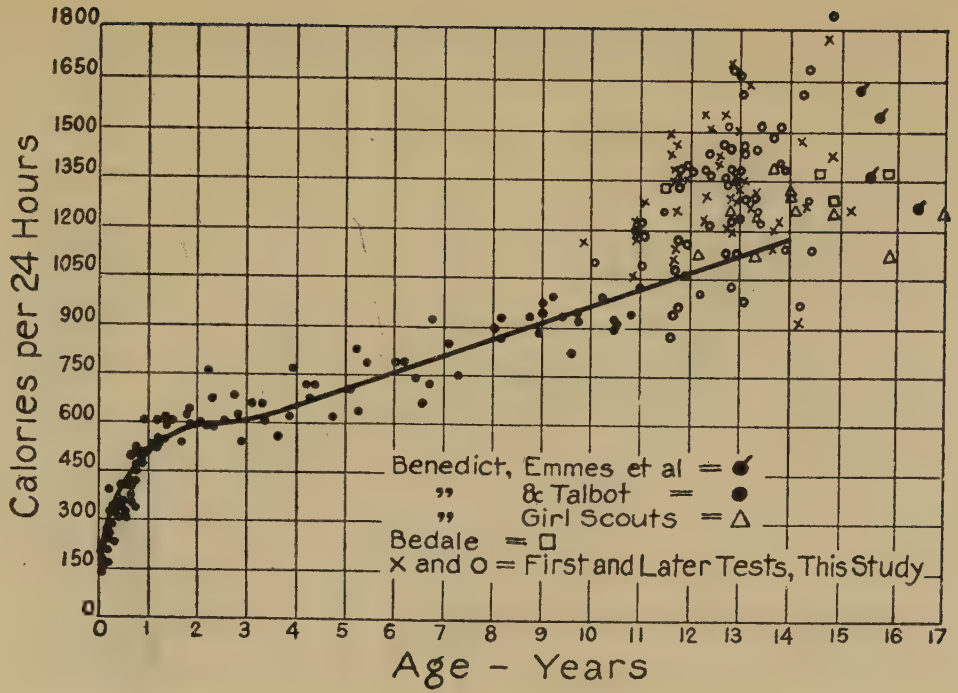

Fig. 1

The Benedict and Talbot curve for basal heat production of girls per 24 hours referred to age with additional cases charted on it as indicated.

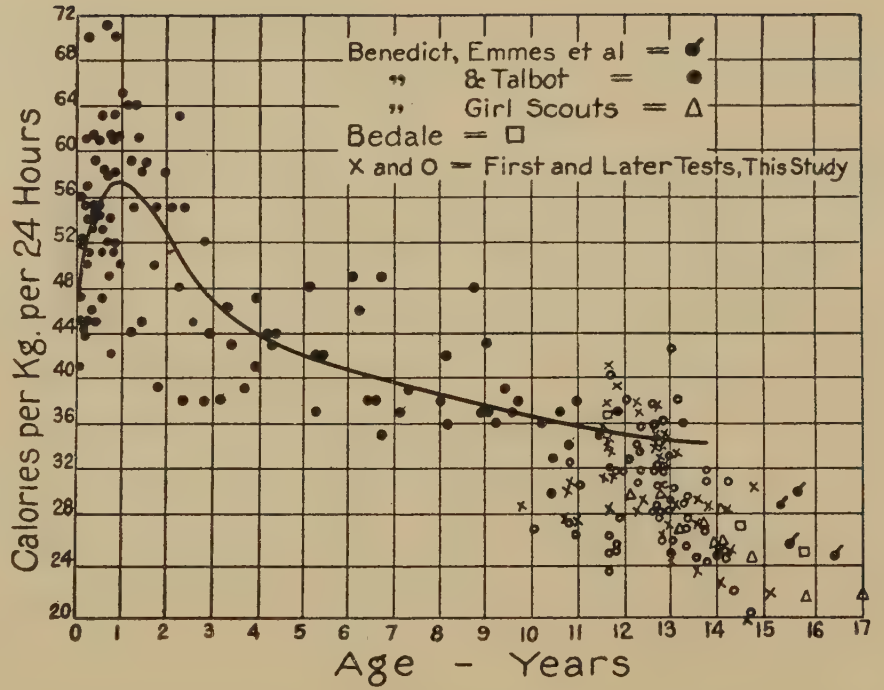

Fig. 2

The Benedict and Talbot curve for basal heat production of girls per kilogram of body weight per 24 hours referred to age with additional cases charted on it as indicated.

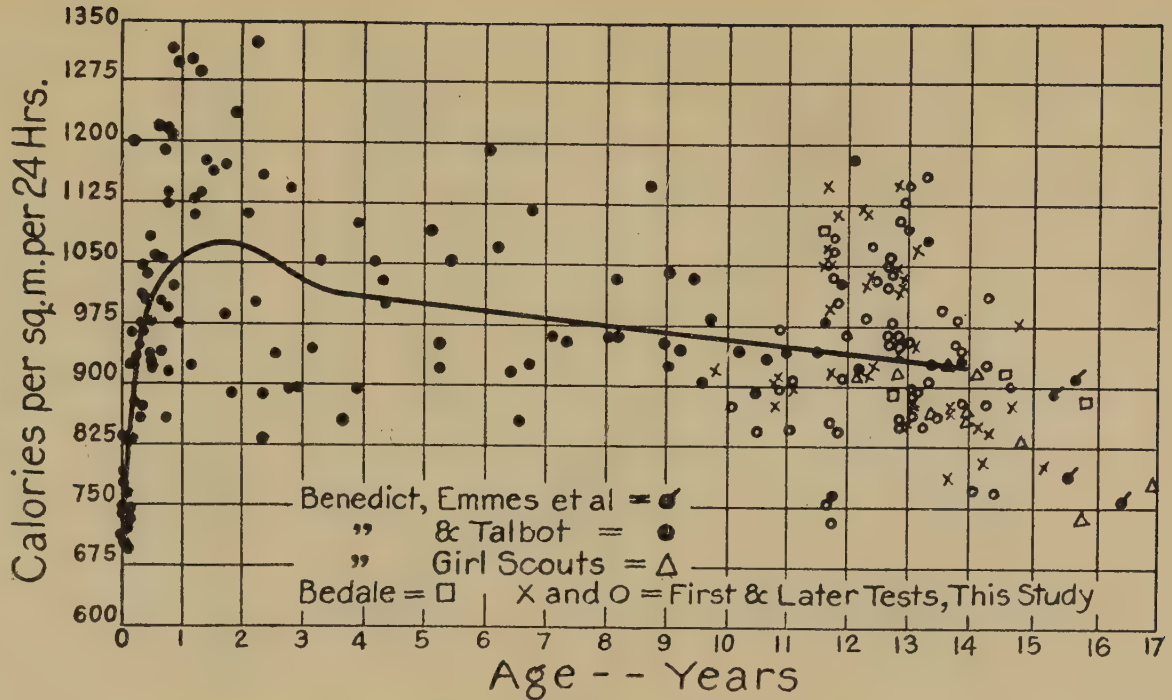

Fig. 3

The Benedict and Talbot curve for basal heat production of girls per square meter of body surface per 24 hours referred to age with additional cases charted on it as indicated.

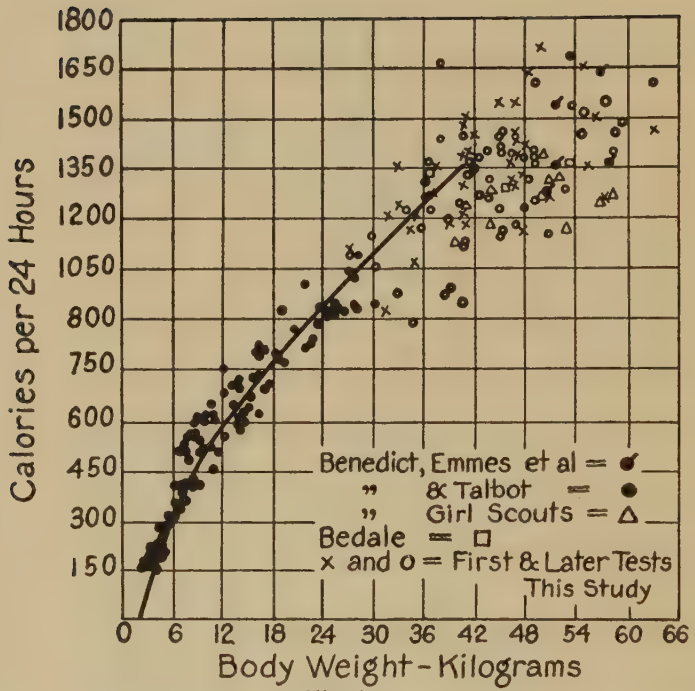

Fig. 4

The Benedict and Talbot curve for basal heat production of girls per 24 hours referred to body weight with additional cases charted on it as indicated. The original scale of this chart has been changed to accommodate the added cases.

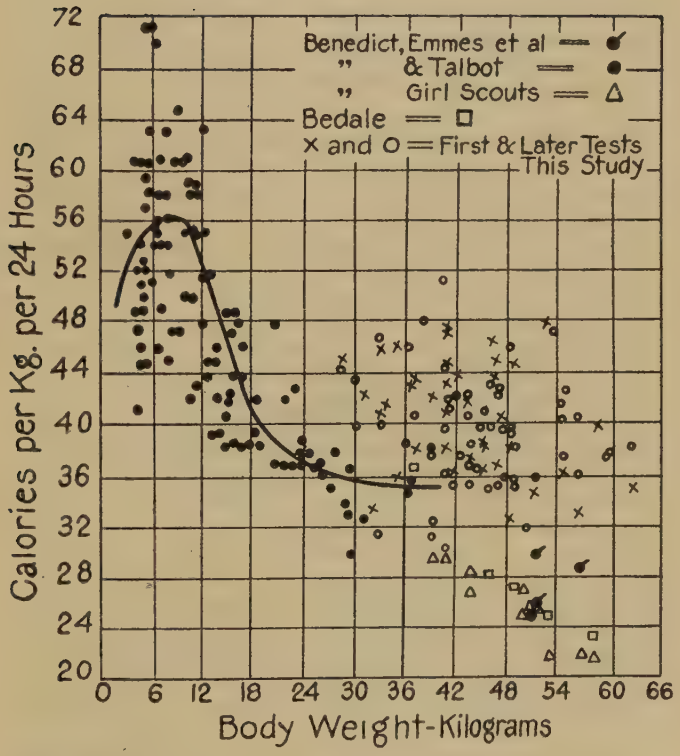

Fig. 5

The Benedict and Talbot curve for basal heat production of girls per kilogram of body weight per 24 hours referred to body weight with additional cases charted on it as indicated. The original scale of this chart has been changed to accommodate the added cases.

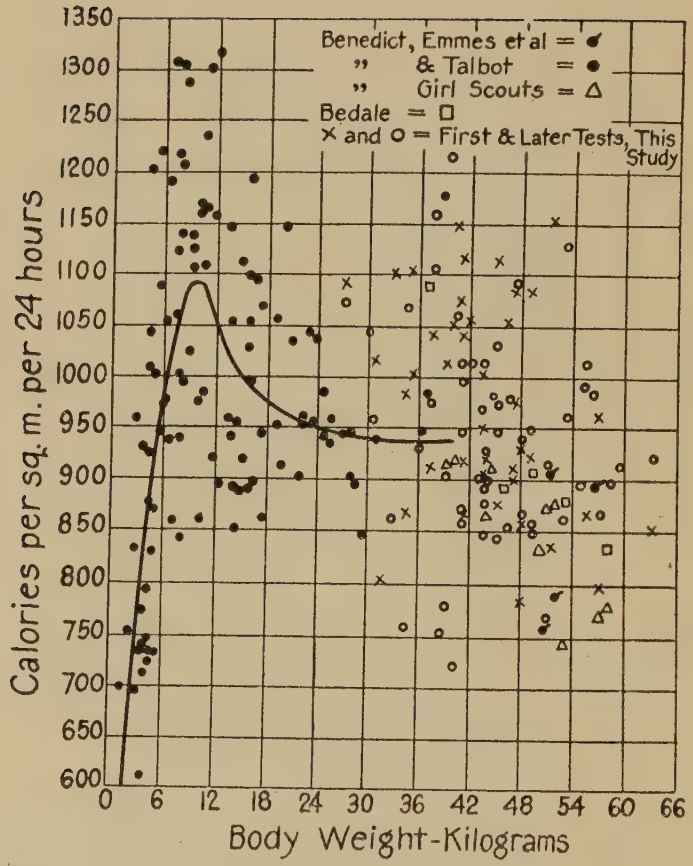

Fig. 6

The Benedict and Talbot curve for basal heat production of girls per square meter of body surface per 24 hours referred to body weight with additional cases charted on it as indicated. The original scale of this chart has been changed to accommodate the added cases.

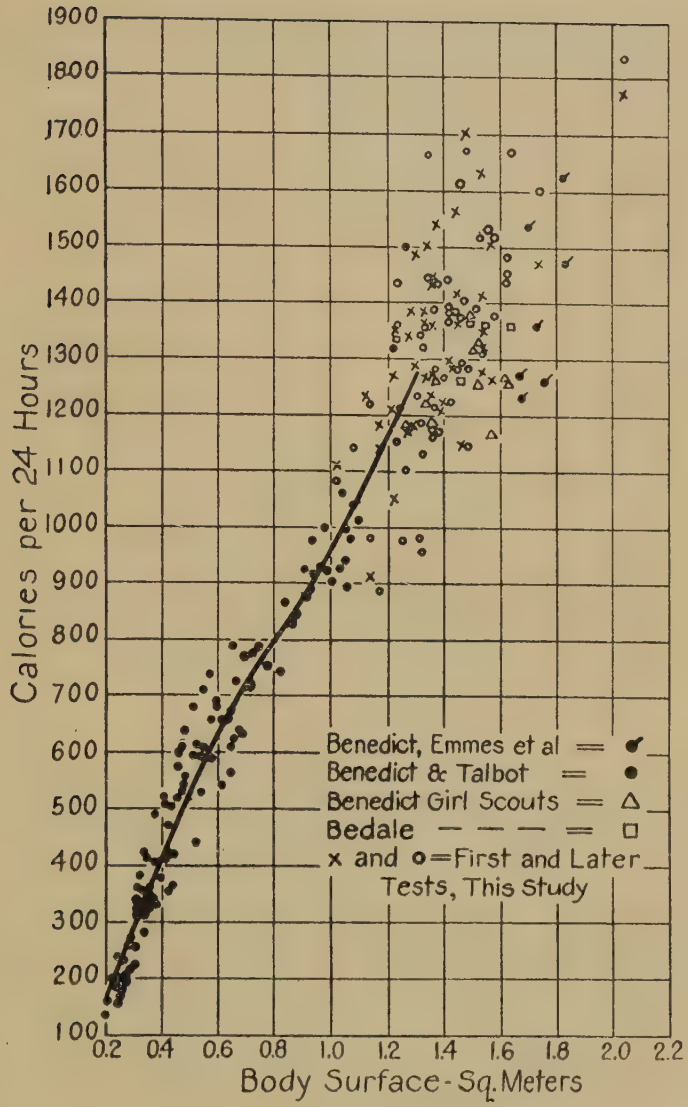

Fig. 7

The Benedict and Talbot curve for basal heat production of girls per 24 hours referred to body surface with additional cases charted on it as indicated. The original scale of this chart has been changed to accommodate the added cases.

referred to the body surface (Figs. 3, 6 and 7). In the four remaining curves it is clear that the new data change the trend of the proposed lines quite definitely.

In order to compare these results with those obtained by DuBois and his associates at the Russell Sage Institute of Pathology [22] on boys of 12 to 14 years, they were plotted on the curve presented in their report as shown in Fig. 8.

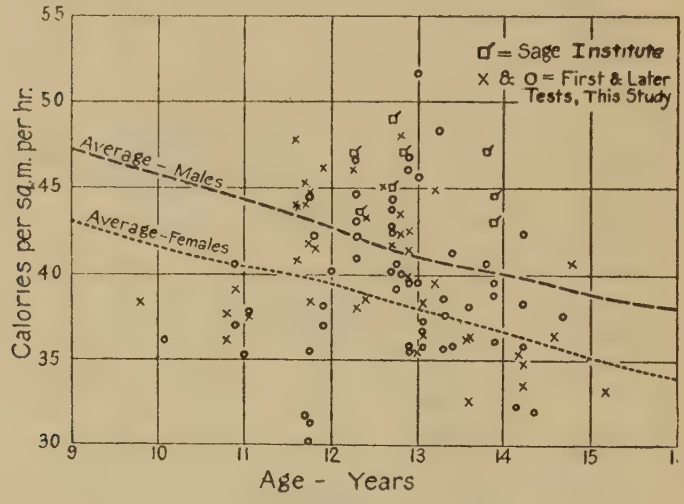

Fig. 8

The results of this study of girls 10 to 15 years of age plotted on that section of the curve presented in the report of DuBois and his associates which showed their results on boys of 12 to 14 years of age.

It will be seen that these results on girls tend to affect the hitherto accepted average line for females in the same way that those on the boys in the same age range affect that for males, i. e., at these ages the actual figures cause the curve for basal metabolism to rise above the downward-sloping straight line which has generally been accepted as the characteristic shape of the curve at this period.

Table V brings together the average figures for basal heat production per 24 hours for the age groups of this study for comparison with those of the other investigators whose results are plotted on the curves. This tabulation shows that

with one exception (Girl Scouts at 14 years) the results reported here are higher than those of Benedict and his associates and lower than those of Bedale.

TABLE V

COMPARISON OF THESE RESULTS WITH THOSE OF OTHER INVESTIGATORS

Age Yrs.	This Study Av. Cals. per 24 hrs.	This Study No. of Subjects	Benedict and Talbot Av. Cals. per 24 hrs.	Benedict and Talbot No. of Subjects	Benedict Girl Scouts Av. Cals. per 24 hrs.	Benedict Girl Scouts No. of Groups	Bedale Av. Cals. per 24 hrs.	Bedale No. of Subjects
11	1191	4	937	4	None	None	1498	3
12	1295	18	1191	3	1180	1	1402	10
13	1365	22	1318	1	1207	2	1478	3
14	1308	13	None	None	1326	4	None	None

COMPARISON OF RESULTS WITH PREVIOUSLY PROPOSED STANDARDS

Since Benedict and Talbot [3] have reported that the Harris and Benedict prediction formula for women cannot safely be used in predicting the basal metabolism of young girls, it has been deemed unnecessary to compare the actual values obtained in this study with those which would be given by that formula.

The Aub and DuBois standards [23] give no values for ages below fourteen. The figure given by Aub and DuBois for girls from 14 to 16 years of age is 43.0 Calories per square meter per hour, which is higher than any result obtained in this series of observations on 14-year-old girls. When this standard figure is compared with the actual results in this study it is found to show an average deviation from them of +18.6 per cent. DuBois [24] has recently made the statement that he thinks the Aub and DuBois figures for children are probably too high.

Dreyer's formula [25] for the basal heat production in 24 hours for females is $C = \frac{\sqrt{W}}{0.1125 \times A^{0.1333}}$ and is applicable, according to Dreyer, to girls and women above the age of five years. In this formula W indicates body weight in grams

and A, age in years at the nearest birthday. When the results predicted by this formula for these subjects are compared with the actual values obtained, it is found that in the 11-year-old group the predicted figures are all higher than the actual; in the 12-year-old group, in 21 of the 30 cases the predicted value is below that actually found; in the 13-year-old group also, the prediction is lower than the actual figure in the majority of the cases (21 out of 38); but in the 14-year-old group the predicted metabolism is higher than the actual in 12 of the 17 cases.

Benedict and Talbot [3] have suggested that, with certain cautions in mind, the curve which they obtained by plotting the basal heat production for 24 hours against body weight (Fig. 4) may be used for predicting the basal metabolism. Wherever possible the probable basal metabolism of each subject of this study was predicted from this curve and also from the Benedict and Talbot curve for the Calories for 24 hours referred to body surface, although this latter curve was not suggested as a means of prediction by these authors. With the exception of one case, in which the predicted figure was 0.6 per cent. below the actual, all predictions from these curves for the 11 and 14-year-old girls were above the actual results, but in the majority of the cases in the 12 and 13-year-old groups the predicted figures were lower than those actually found. Table VI shows the average percentage deviations of all predicted values from the actual results when found both with and without regard to sign.

TABLE VI

AVERAGE PERCENTAGE DEVIATION OF THE PREDICTED VALUES FROM THE ACTUAL RESULTS

	Aub and DuBois		Dreyer		Benedict and Talbot Curve for Cals. Referred to Wt.		Benedict and Talbot Curve for Cals. Referred to Surface	
Age Yrs.	Without regard to sign	With regard to sign	Without regard to sign	With regard to sign	Without regard to sign	With regard to sign	Without regard to sign	With regard to sign
11	....	....	8.7*	+8.7	5.3	+5.0	6.7*	+6.7
12	....	....	8.8	—1.0	13.2	—2.7	11.6	—6.1
13	....	....	7.5	—1.8	8.9	—6.5	7.0	—4.3
14	18.6*	+18.6	10.0	+7.4	17.5*	+17.5	16.6*	+16.6

* All predicted values were higher than the observed.

Table VII shows in how many instances in each age group the predicted figure was higher or lower than the actual result.

TABLE VII

SHOWING THE NUMBER OF CASES IN WHICH THE PREDICTED VALUES WERE HIGHER OR LOWER THAN THE ACTUAL RESULTS

	Aub and DuBois		Dreyer		Benedict and Talbot Curve for Cals. Referred to Wt.		Benedict and Talbot Curve for Cals. Referred to Surface	
	Predicted below actual	Predicted above actual	Predicted below actual	Predicted above actual	Predicted below actual	Predicted above actual	Predicted below actual	Predicted above actual
Age Yrs.	No. cases	No. cases	No. cases	No. cases	No. cases	No. cases	No. cases	No. cases
11	..	..	0	8	1	3	0	3
12	..	..	21	9	8	2	9	1
13	..	..	21	17	9	2	7	2
14	0	17	5	12	0	3	0	3

It is apparent that in general the standards proposed hitherto predict results which are too high for girls of eleven and fourteen years and too low for twelve and thirteen year old girls.

For comparison with Figures 1, 4 and 7 the basal heat per 24 hours has been plotted against height in Figure 9. These curves indicate that the basal heat production per 24 hours bears a more nearly straight-line relationship to body surface and to height than it does to age or body weight. Benedict [26] has recently noted this apparently closer relationship for his subjects between the basal heat per 24 hours and height than between the former and body weight. As another way of studying this, the average value for each age group of each of the ratios (1) basal heat per 24 hours to weight, (2) basal heat per 24 hours to surface area, and (3) basal heat per 24 hours to height was determined and the coefficient of variation calculated for the four values (one for each age group) of each ratio. The results are given in Table VIII.

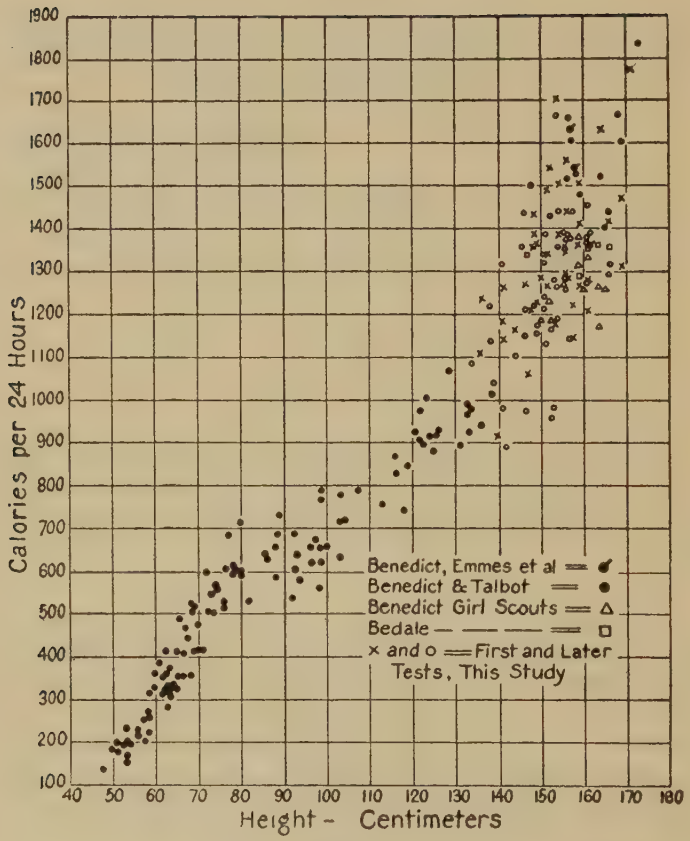

Fig. 9

The basal heat production of girls per 24 hours referred to height for which no curve has as yet been drawn. These cases are plotted for comparison of the line they would give with the lines of Figs. 1, 4, and 7.

TABLE VIII

COMPARISON OF THE RATIOS OF BASAL HEAT PER 24 HOURS TO HEIGHT, AREA, WEIGHT

Age Years	Av. Value of Heat ÷ Height	Av. Value of Heat ÷ Area	Av. Value of Heat ÷ Weight
11	7.90	900	29.2
12	8.61	991	32.3
13	8.87	985	31.1
14	8.23	880	26.7
Mean	8.40	939	29.8
Standard Deviation	±0.37	±49.6	±2.1
Coeff. of Variation	4.4%	5.3%	7.1%

The coefficient of variation for the ratio of heat to height was found to be 4.4 per cent., for that of heat to area, 5.3 per cent., and for that of heat to weight, 7.1 per cent.

The conclusion to be drawn from this study of these ratios is such as is indicated by the curves, viz., that the correlations of heat to height and heat to body surface are closer than that of heat to body weight for girls of these ages. This would indicate that height and body surface may be better bases from which to predict basal metabolism for young girls than either weight or age.

SUMMARY

The results of three hundred and sixty-two determinations of the basal metabolism of healthy normal girls from 11 to 14 years of age are presented and compared with such figures and proposed standards as exist for this age range. Forty-three different girls have served as subjects, fifteen of whom have been followed through two or three years, making the total number of cases fifty-eight.

The average oxygen consumption per minute is found to be for 11 years, 171 cc.; for 12 years, 85 cc.; for 13 years, 196 cc.; and for fourteen years, 188 cc.

The average Calories per 24 hours for 11 years is found to be 1191; for 12 years, 1295; for 13 years, 1365; and for 14 years, 1308.

The average Calories per square meter of body surface per hour for 11 years is found to be 37.5; for 12 years, 41.3; for 13 years, 41.0; and for 14 years, 36.6.

The average Calories per square meter per 24 hours for 11 years is found to be 900; for 12 years, 990; for 13 years, 985; and for 14 years, 880.

The average Calories per kilogram of body weight per 24 hours for 11 years is found to be 29.2; for 12 years, 32.3; for 13 years, 31.1; and for 14 years, 36.7.

The results are compared with the values predicted by the standards of Aub and DuBois, the Dreyer formula, and the curves of Benedict and Talbot for total heat referred to weight and total heat referred to surface area. It is shown that in general the standards for girls proposed up to this time predict values which are too high for girls of eleven and fourteen years of age and too low for girls of twelve and thirteen.

The more nearly straight-line relationship noted between heat and body surface and between heat and height than exists between heat and age or between heat and weight for girls of these ages indicates that body surface and height are better bases from which to predict the basal metabolism of young girls than either age or weight.

On comparison with the results obtained by other investigators on normal healthy girls of these ages the results of this study are found to average somewhat higher than the majority of the cases hitherto reported in the literature. Since the results of this study have been obtained from more determinations for these ages than are represented in any other work reported and are all from individuals rather than groups, it would appear that the basal metabolism of girls at these ages is higher than has been indicated heretofore by other investigators.

BIBLIOGRAPHY

[1] Lusk. A History of Metabolism. Endocrinology and Metabolism, III, 2. New York, D. Appleton & Co., 1922.

[2] Harris and Benedict. A Biometric Study of Basal Metabolism in Man. Carnegie Inst. Washington, Pub. No. 279, 1919.

[3] Benedict and Talbot. Metabolism and Growth from Birth to Puberty. Carnegie Inst. Washington, Pub. No. 302, 1921.

[4] Magnus-Levy and Falk. Der Lungengaswechsel des Menschen in den verschiedenen Altersstufen. Archiv. f. Anat. u. Physiol. 1899, Supp.-Bd., 314.

[5] Andral and Gavarret. Ann. d. Chim. et d. Phys. **8,** 129 (1843, Sér. 3). Cited by Magnus-Levy and Falk and by Benedict and Talbot.

[6] Scharling. Ann. d. Chem. u. Pharm. **45,** 214 (1843); reprinted in Ann. d. Chim. et d. Phys., **8,** 478 (1843) Sér. 3). Cited by Magnus-Levy and Falk and by Benedict and Talbot.

[7] Speck. Physiologie des menschlichen Athmens. Leipzig, 1892. Cited by Magnus-Levy and Falk and by Benedict and Talbot.

[8] Sondén and Tigerstedt. Untersuchungen über die Respiration und den Gesammtstoffwechsel des Menchen. Skand. Arch. f. Physiol. **6,** 1 (1895).

[9] Benedict, Emmes, Roth and Smith. The Basal Gaseous Metabolism of Normal Men and Women. J. Biol. Chem. **18,** 139 (1914).

[10] Benedict and Hendry. The Energy Requirements of Girls from 12 to 17 Years of Age. Boston Med. Surg. J. **184,** 217-222, 257-262, 282-286, 297-306, 329-334 (1921).

[11] Benedict. The Basal Metabolism of Young Girls. Boston Med. Surg. J. **188,** 127-138 (1923).

[12] Bedale. Energy Expenditure and Food Requirements of Children at School. Proceedings of the Royal Society, London, B. **94,** 368-404 (1923).

[13] Benedict. A Portable Respiration Apparatus for Clinical Use. Boston Med. Surg. J. **178,** 667-678 (1918). Notes on the Use of the Portable Respiration Apparatus. Boston Med. Surg. J. **182,** 243-245 (1920).

[14] Boothby and Sandiford. Basal Metabolic Rate Determinaations. Philadelphia, W. B. Saunders Company, 1920, pp. 25-29.

[15] Du Bois, E. F. The Basal Metabolism in Fever. J. Am. Med. Assoc. **77,** 352-357 (1921).

[16] Benedict and Higgins. Effects on Men at Rest of Breathing Oxygen-rich Gas Mixtures. Am. J. Physiol. **28,** 1 (1911).

[17] Baldwin and Wood. Weight—Height—Age Tables. Mother and Child, July 23, 1923, Supplement. New York, American Child Health Association. Also, Baldwin, B. T. The Use and Abuse of Weight—Height—Age Tables as Indexes of Health and Nutrition. J. Am. Med. Assoc. **82,** 1 (1924).

[18] Dreyer. The Assessment of Physical Fitness. London, Cassell & Company, 1920.

[19] Du Bois, D. and Du Bois, E. F. A Formula to Estimate the Approximate Surface Area if Height and Weight be Known. Arch. Int. Med. **17,** 863 (1916).

[20] Carpenter and Fox. Alcohol Check Experiments with Portable Respiration Apparatus. Boston Med. Surg. J. **189,** 551 (1923).

[21] Carpenter. Tables, Factors and Formulas for Computing Respiratory Exchange and Biological Transformations of Energy. Carnegie Inst. Washington, Pub. No. 303, 1921.

[22] Du Bois, E. F. The Metabolism of Boys 12 and 13 Years Old Compared with the Metabolism at Other Ages. Arch. Int. Med. **17**, 887 (1916). Olmstead, Barr and Du Bois. Metabolism of Boys 12 and 14 Years Old. Arch. Int. Med. **21**, 621 (1918).

[23] Aub and Du Bois. The Basal Metabolism of Old Men. Arch. Int. Med. **19**, 823 (1917).

[24] Du Bois, E. F. Private Communication.

[25] Dreyer. The Normal Basal Metabolism in Man and Its Relation to the Size of the Body and Age, Expressed in Simple Formulae. Lancet, 1920, II, 289.

[26] Benedict. Private Communication.

VITA

Grace MacLeod was born in Rothesay, Scotland, August 6, 1878. She was educated in the public schools of Cambridge, Massachusetts; attended the Massachusetts Institute of Technology from 1897 to 1901, receiving the degree of Bachelor of Science in 1901; and has been a graduate student in the Faculty of Pure Science, Columbia University, 1911-1917 and 1921-1924, receiving the degree of Master of Arts in 1914.

She taught chemistry and physics in secondary and technical schools from 1901 to 1918. During the years 1918 and 1919 she was assistant editor of the Journal of Industrial and Engineering Chemistry. Since 1919 she has been Instructor in Nutrition and Food Economics in Teachers' College, Columbia University, and also, since 1921, Co-operating Investigator with the Nutrition Laboratory (Boston, Mass.) of the Carnegie Institution of Washington.

She was co-author with James F. Norris of a paper entitled "On the Preparation of Triphenylmethane," published in the American Chemical Journal, XXVI, 499-505 (1901).

With Mary S. Rose she was co-author of the following papers:

"Some Human Digestion Experiments with Raw White of Egg." J. Biol. Chem. L, 83-88 (1922).

"Some Human Digestion Experiments with Raw White of Egg. II. The Digestibility of Unbeaten in Comparison with Beaten Whites." J. Biol. Chem. LVIII, 369-371 (1923).

"The Almond as a Source of the A Vitamin." Proc. Soc. Exp. Biol. Med. XIX, 391-393 (1922).

"Experiments on the Utilization of the Calcium of Almonds by Man." J. Biol. Chem. LVII, 305-315 (1923).

"Maintenance Values for the Proteins of Milk, Bread-and-Milk, Meat, and Soy Bean Curd in Human Nutrition." Proc. Soc. Exp. Biol. Med. XXI, 143-144 (1923).

Lansing-Broas Ptg. Co., Inc.
229-233 Union St., Poughkeepsie, N. Y.